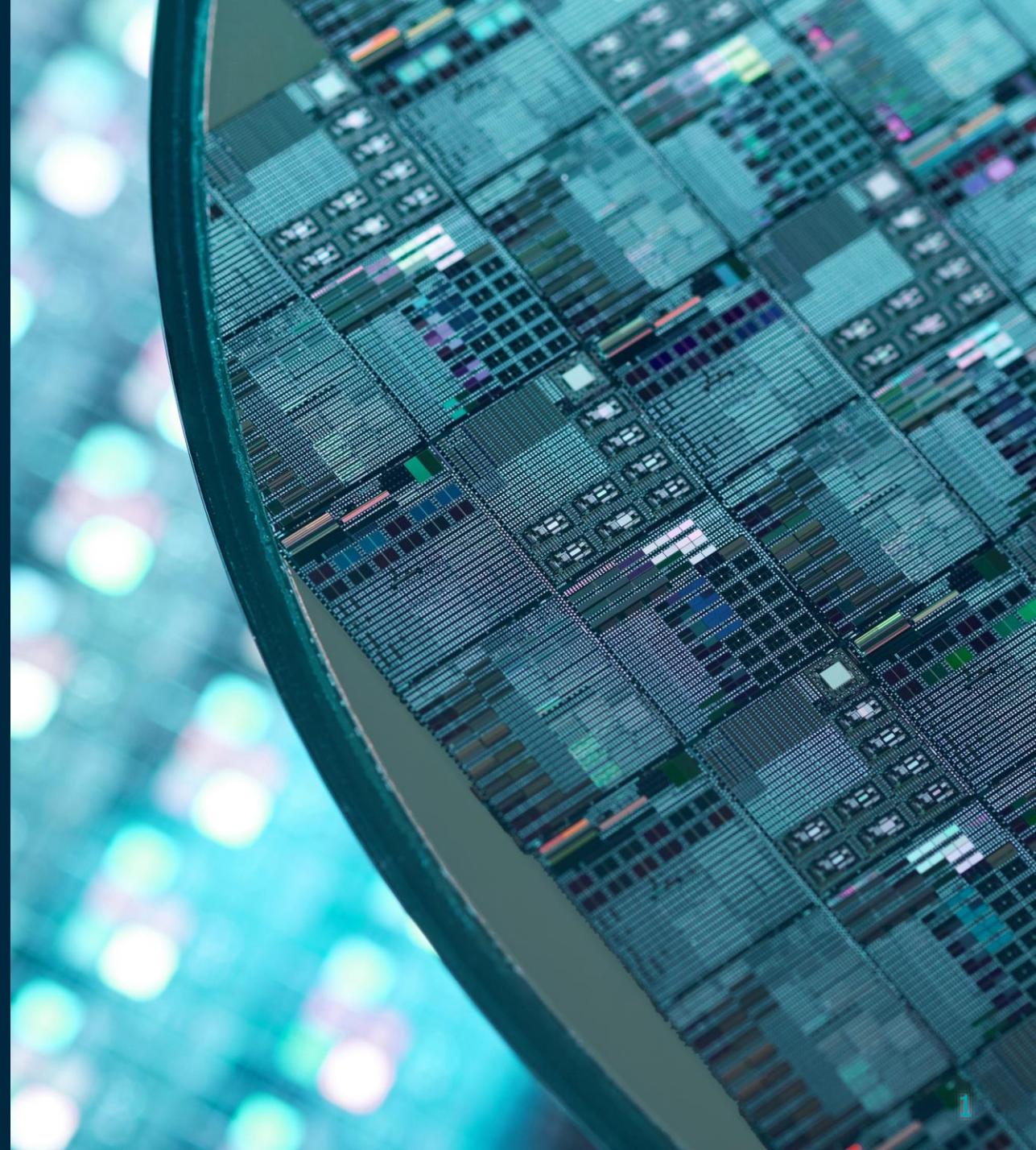




A guide to full autonomous operation using MLTRL calibration on and off the wafer

TMA13
Gavin Fisher



What is Autonomous RF?

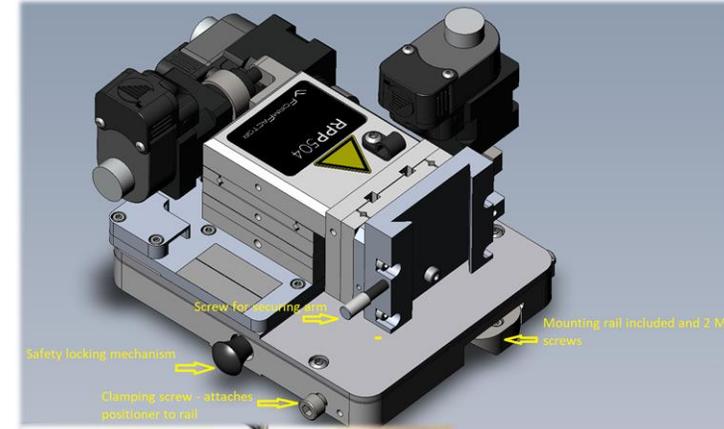


- Autonomous RF system allows all aspects of on wafer RF test and calibration beyond initial setup to be carried out without human intervention
- Involves the intelligent use of
 - Motorised positioners to adjust probe spacing
 - Pattern recognition to find probes and wafer
 - Auto focusing evue microscope to gain Z position data
 - WinCalXE™ calibration software
 - Velox software

What's needed?

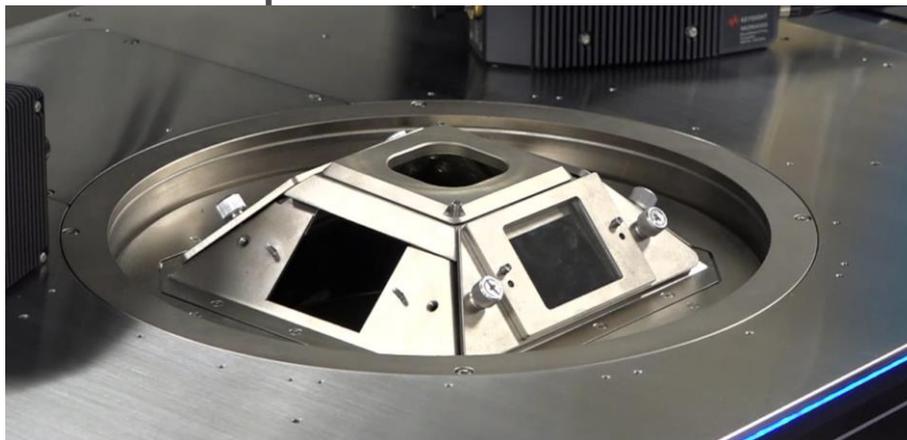
The solutions includes:

- **RPP 504** motorized positioners (Minimum of 1) and platen adaptors for Summit 12k
- **Application specific RFA Arm** - 67 GHz Coax, N5291A 130 GHz coax, VDI Waveguide using Infinity or DMPI probes
- **MPX or ECX box** used to drive positioners – either type now with any station (Velox 3.3)
- **eVue** Vision system (handles all the necessary pattern recognition and focus scans)
- **Velox 3.x with Auto RF** software license required for full automation
- **WinCalXE 4.8** or higher



What's needed – Shielded system?

- FlexShield™ boot kit - allows frictionless probe motion in TopHat
- RF Tophat - for flexshield if dry/dark / shielded is required and application above 67 GHz
- Sub67 use only needs regular 8 sided tophat

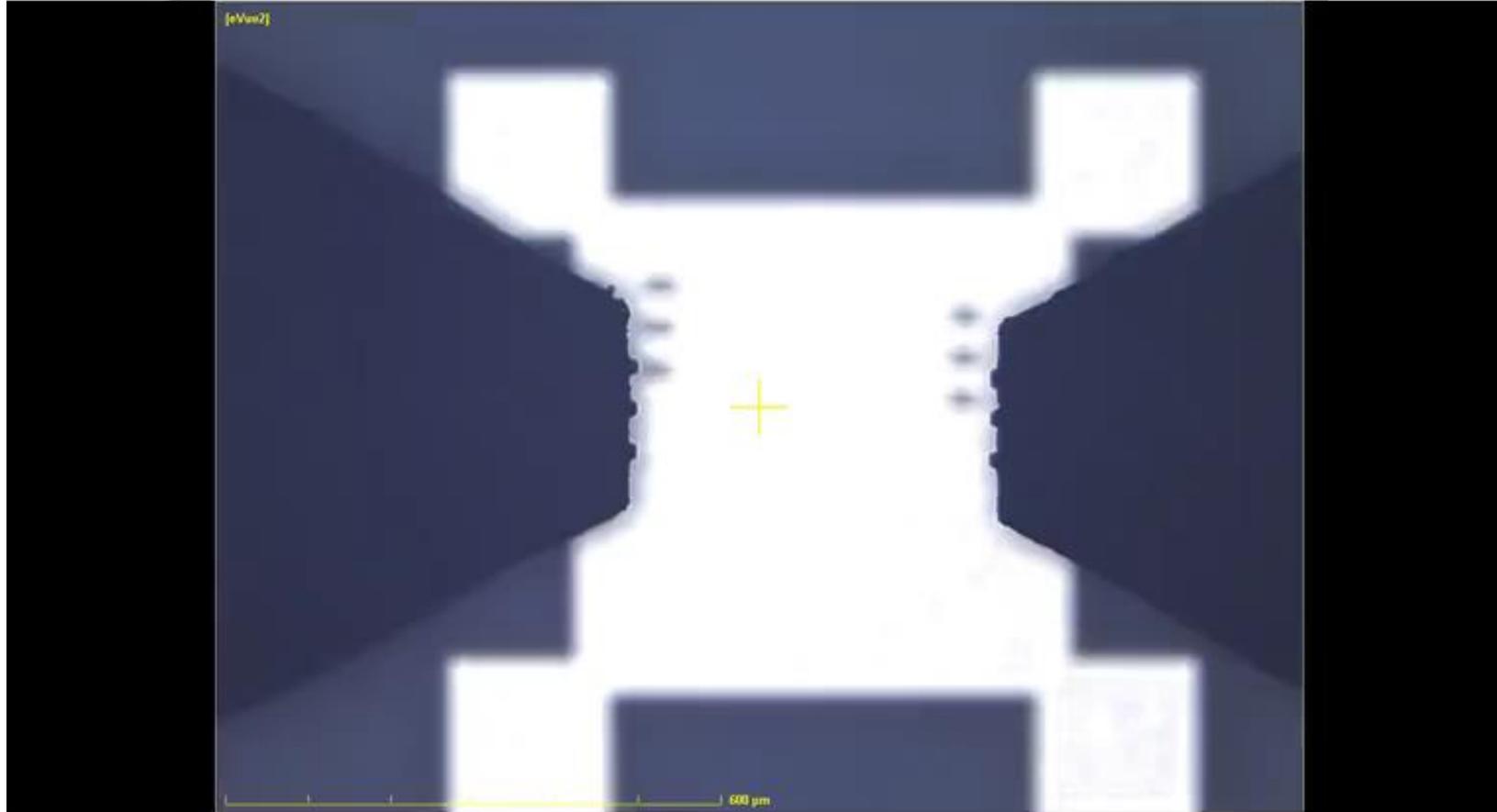


Pain points – Probe Expansion

- Probes grow / retract with temperature in X and Z
- Some movement in Y but comparatively minimal
- For significant thermal changes evaluate theta also
- Chuck expands in XYZ as a function of displacement from centre and also shifts axially

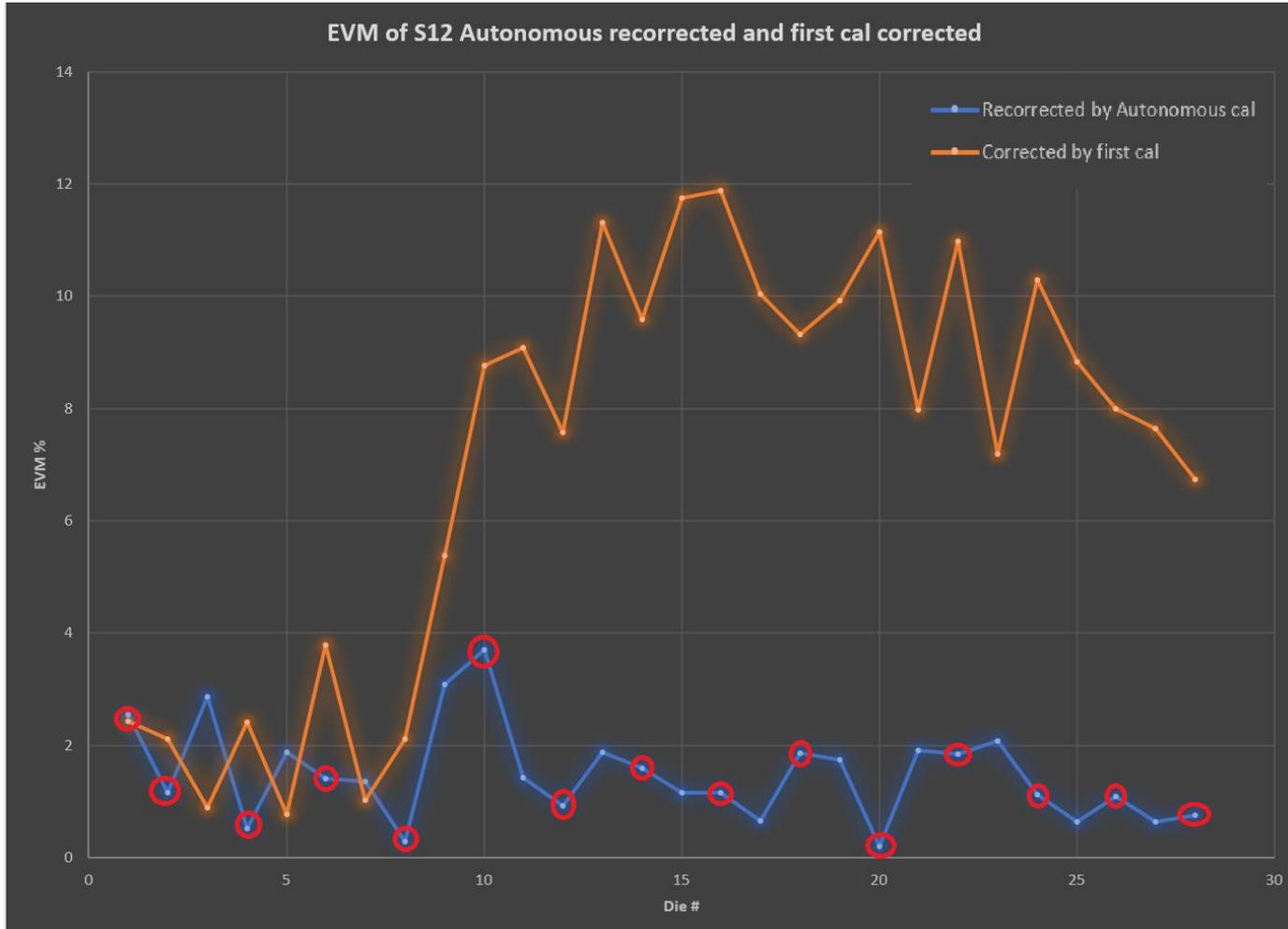


Pain points - Probe expansion from Ambient to 125 degree Summit 12k (video)



- Probes grow as temperature goes from 25 to 125 and then shrink going to 25

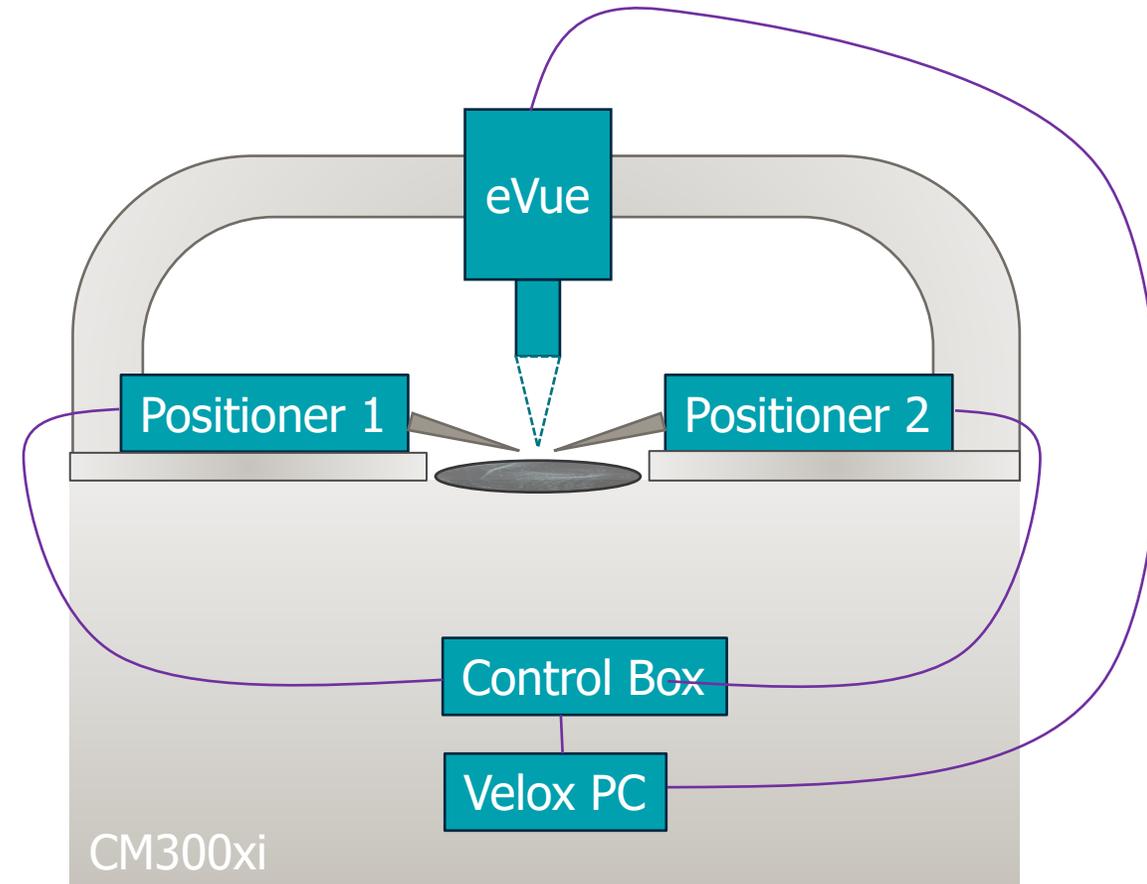
Pain points – Drift means recalibration



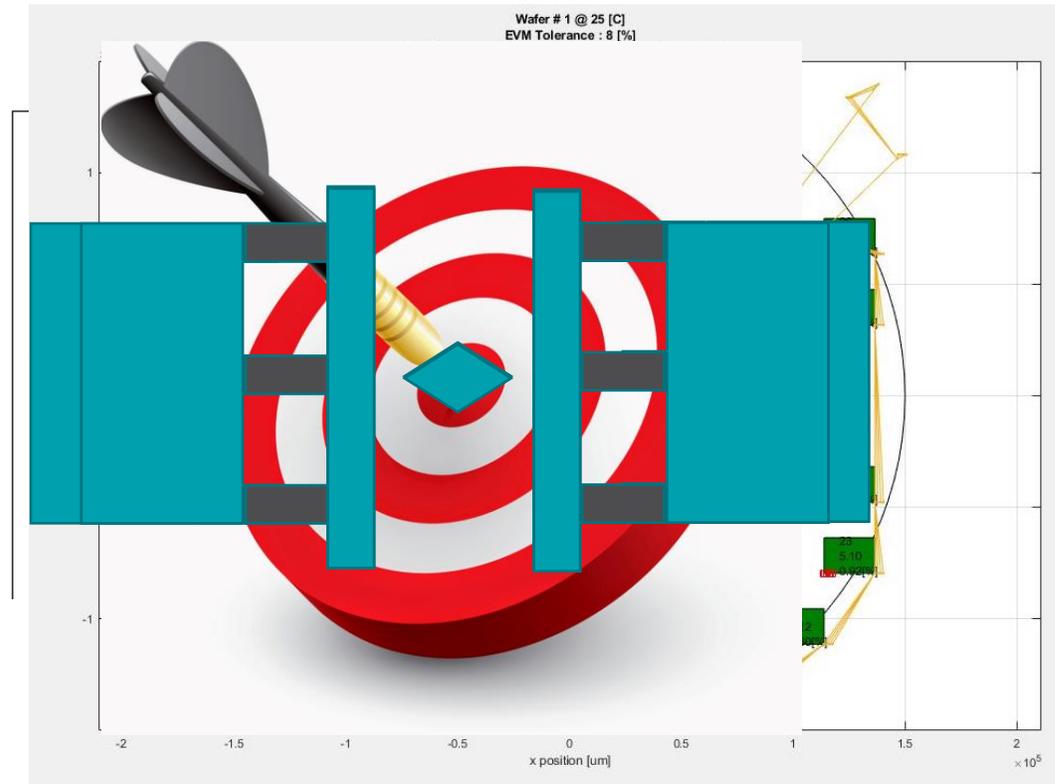
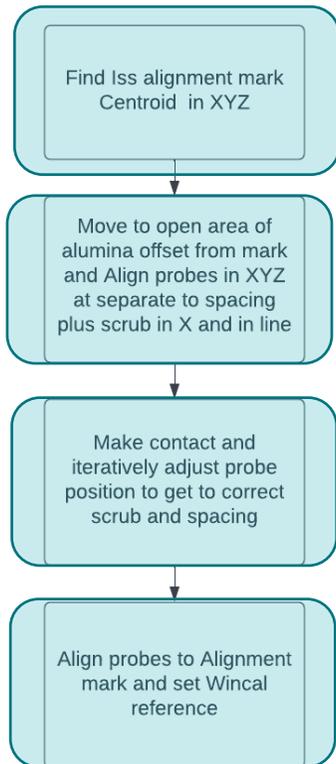
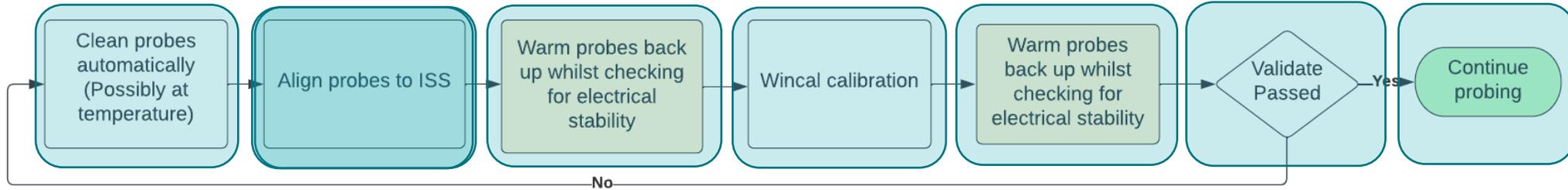
- Blue delta is using Autonomous
- Orange is same measurements but using original cal (system drifted as probe temperature changes)

How does Autonomous RF Work – Die stepping

- Probes are setup manually by user on a home device with appropriate placement and scrub (ideally using optical align markers)
- Velox vision system training learns the probe XYZ position
- When automating, Velox reproduces original trained geometry moving positioners and chuck until tolerance reached during each alignment cycle
- Autonomous RF difference from DC automation (Vuetrack pro) is addition of Monitor step to see if cal is valid still....If not a recalibration is triggered

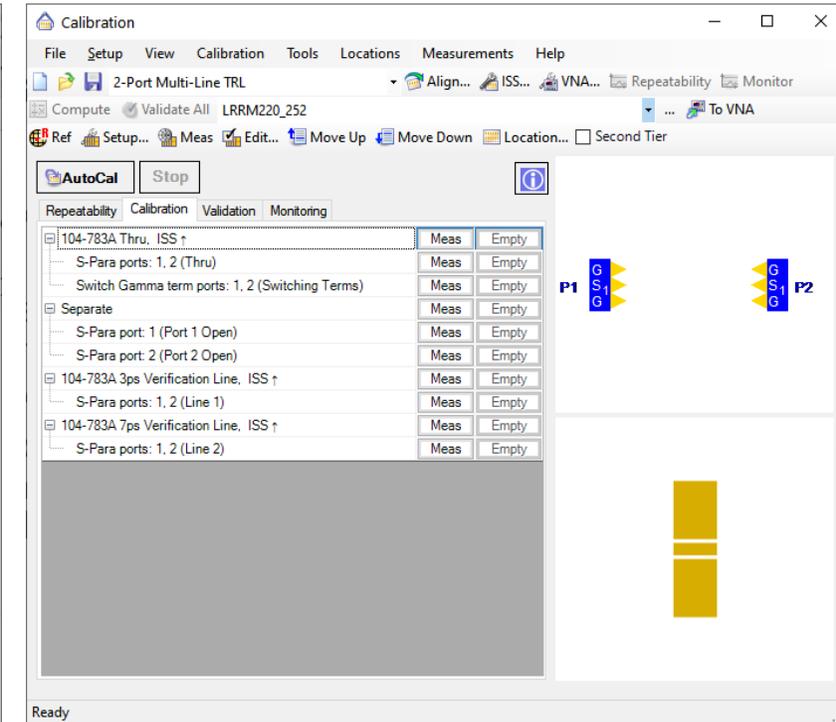
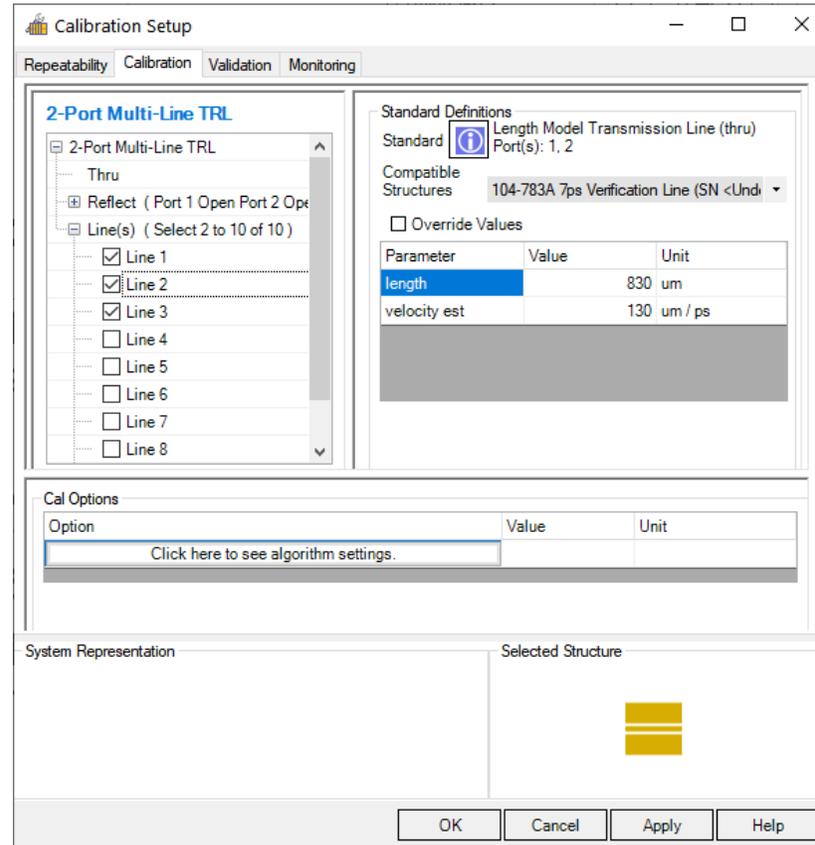


How does Autonomous RF Work – Calibration



How to setup for MLTRL in WinCal on an Auxiliary site

- MLTRL with autonomous using an ISS is purely an extension of standard LRRM approach
- Autonomous finds correct spacing at the alignment mark but any ISS cal substrate or calibration approach will work
- If ISS is known to WinCal then all probe and chuck moves in an autocal performed automatically by WinCal



Video – Setting up autonomous for MLTRL using ISS

Control Center: Chuck

Predefined Positions

Material Handling

XY Joystick

Z Setup

Position From Home

Chuck From Home			Positioner 1 From Home			Positioner 2 From Home		
X	0.0 μm		X	-13.8 μm		X	6.2 μm	
Y	0.0 μm		Y	-22.3 μm		Y	-3.1 μm	
Z	0.0 μm		Z	-79.8 μm		Z	0.1 μm	
T	0.3117 $^\circ$							

WinCal XE 4.9 - RF Calibration, ...

MLTRL1.wcf2.wcf - Calibr...

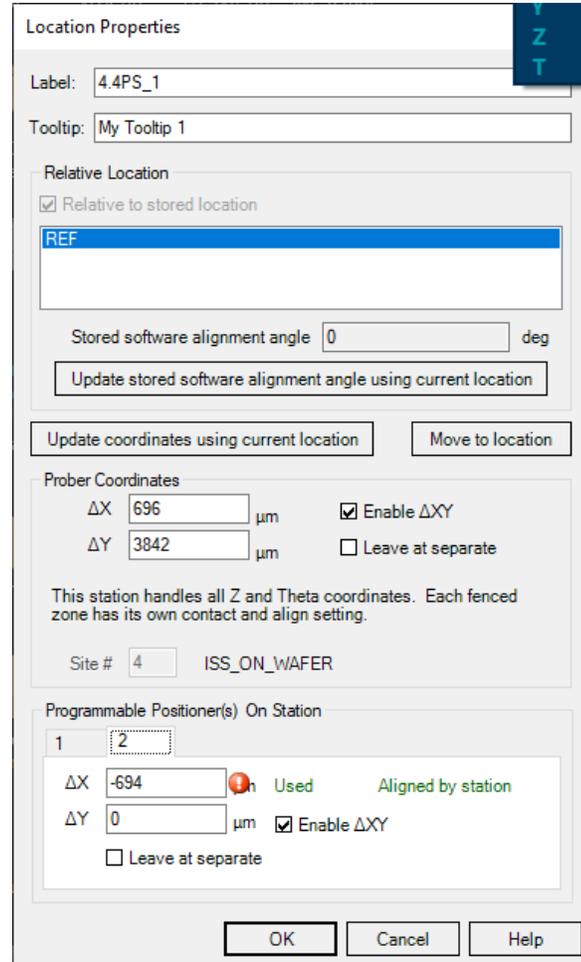
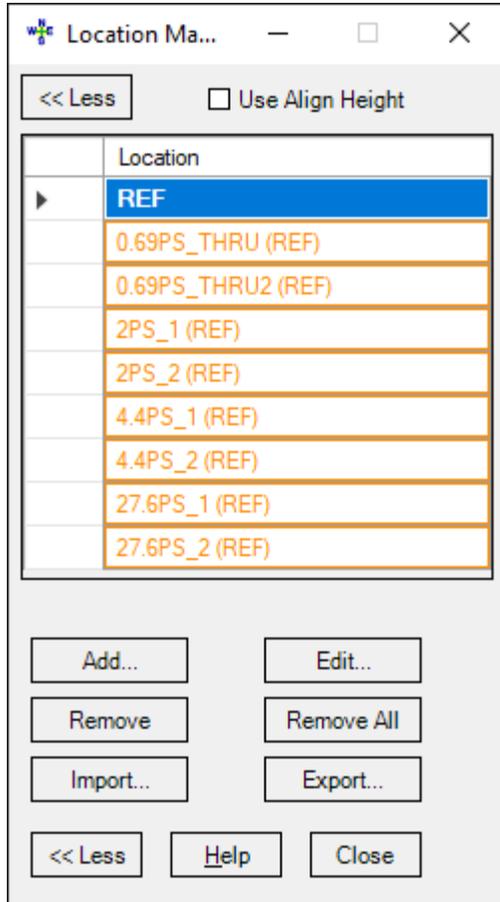
TightVNC Viewer

S11 LogM 10.00dB/ 0.00dB

WinCal Measuring raw data. Sic = 1...

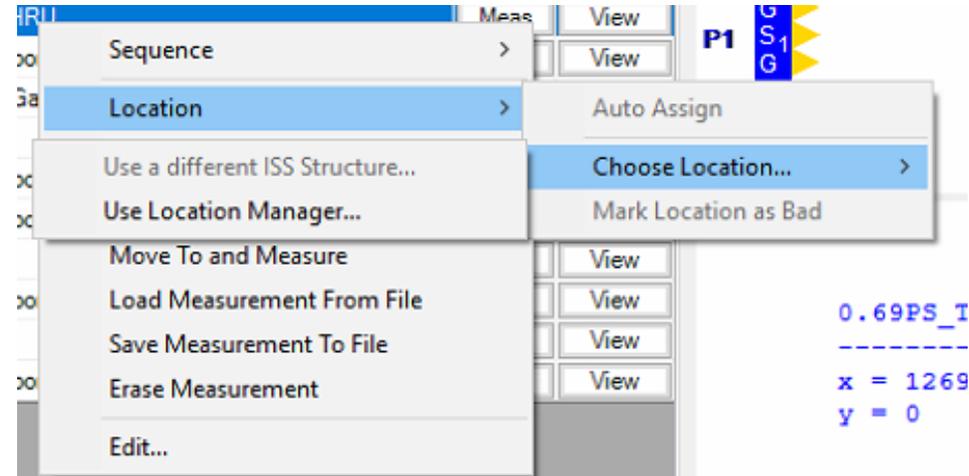
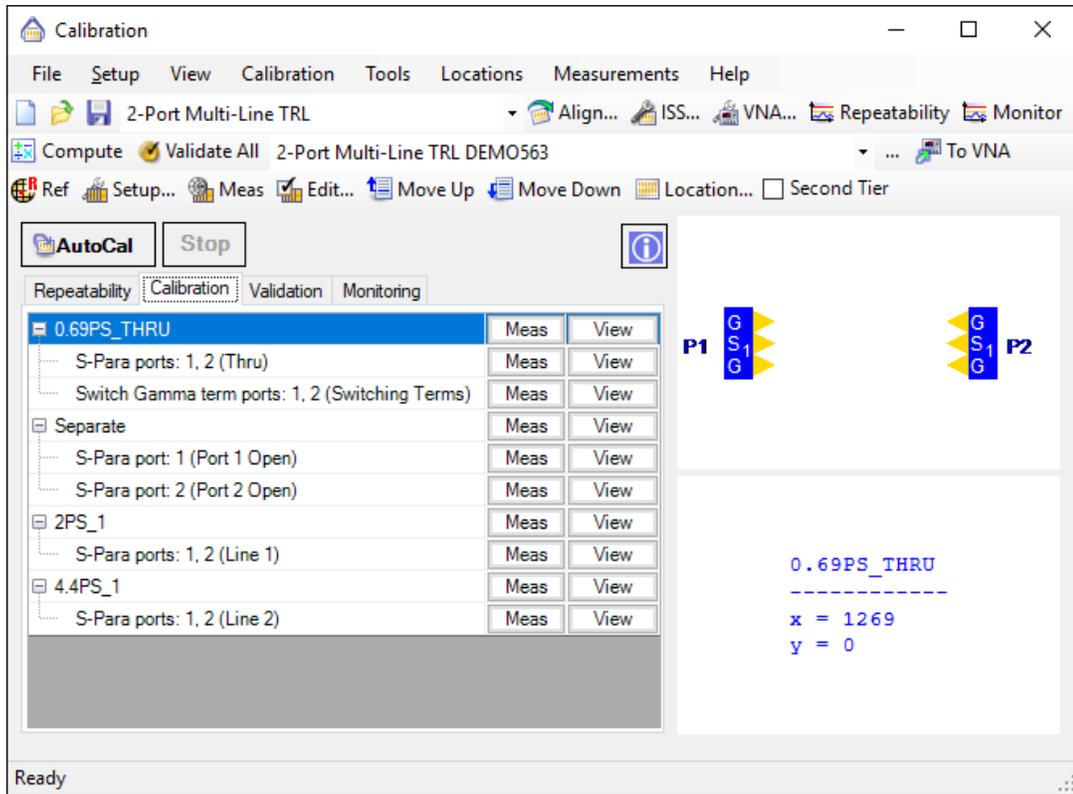
4:21 AM 5/11/2022

MLTRL Using location manager



- Location manager is one of the simplest and safest means within WinCal to define custom standard arrangement
- Each location has its own chuck and positioner location
- Locations can be used for calibration OR for custom device measurements in test executive

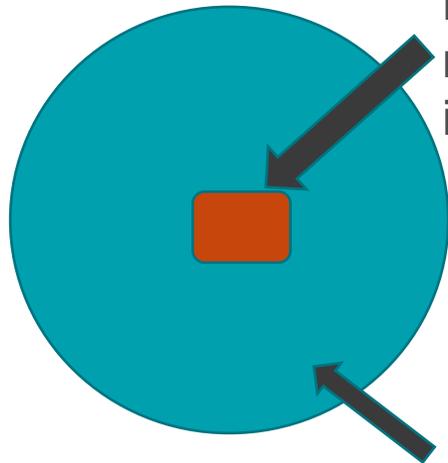
Setup of MLTRL using custom locations



- Calibration measurements point to the appropriate location from location manager
- Its also possible to create a custom ISS in the same way as Formfactor do but this is a little time consuming but good for greater flexibility

Autonomous MLTRL On the wafer

- Autonomous system expects the ISS to be on a separate auxiliary chuck from the wafer
- However its possible for an auxiliary chuck to actually be a region of the main wafer chuck
- To add a site increase the Aux chuck count by 1, restart Velox and then follow the auxiliary chuck setup wizard
- ONLY the new Aux site should be the Cal substrate
- Each aux site has independent theta, home and Z contact



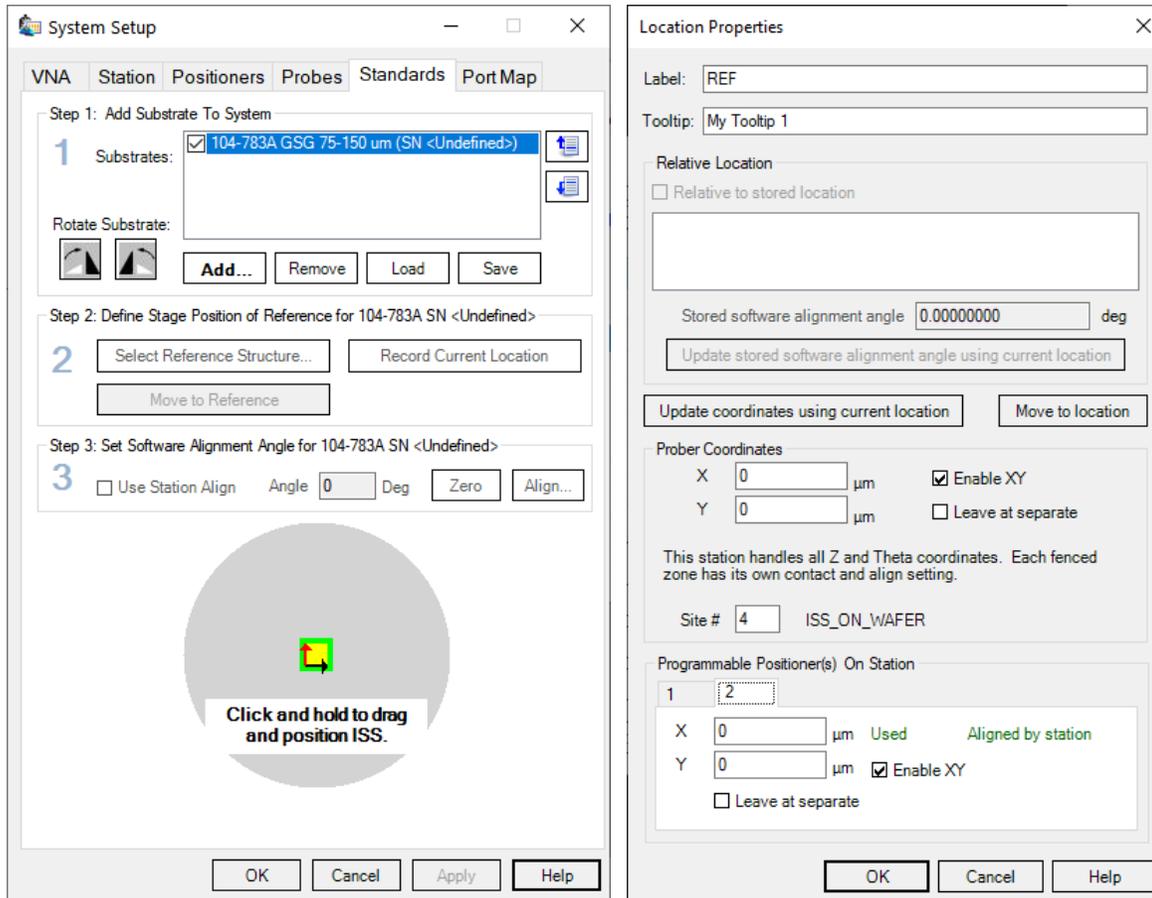
Aux site where the MLTRL standards reside – Aux site 4 in this case

Main wafer chuck – Aux site 0

The screenshot shows the Velox Settings interface. The 'General' tab is selected, and the 'Number of AUX Sites' is set to 4. The 'Allow Cleaning At Non-Ambient Temperatures' toggle is turned on. The 'AUX Sites' section shows four sites configured:

Site	Name	Type	Contact Height
Site 1	ISS	Unknown	5263.00µm
Site 2	CLEAN	Pad Cleaner	4861.01µm
Site 3	REF	Clean Reference	5224.57µm
Site 4	ISS ON WAFER	Cal Substrate	4751.20µm

Autonomous MLTRL On the wafer



- Autonomous expects a regular iss on an aux site
- One (any type) must be specified kind of as a placeholder and its reference set to virtual aux site home position
- Reference site for location manager is set as home also (ie iss home and location manager home are the same place)
- Autonomous is trained as normal and automation functions properly
- If different line set are needed due to wear a separate cal wcf file can be created that references the different locations which would be opened by test exec on demand

Training Autonomous on the wafer

Control Center: Positioner 2

Predefined Positions

XY Joystick

Z Setup

Position From Home

Check From Home	Positioner 1 From Home	Positioner 2 From Home
X: 0.0 µm	X: 0.0 µm	X: 0.0 µm
Y: 0.0 µm	Y: 0.0 µm	Y: 0.0 µm
Z: 0.0 µm	Z: -0.1 µm	Z: 0.1 µm
T: 0.3140 °		

6702.4

S: 300.0 A: 80.0 0.1 Contact 6702.3

X: 0.0 µm
Y: 0.0 µm
Z: 0.1 µm

300 µm

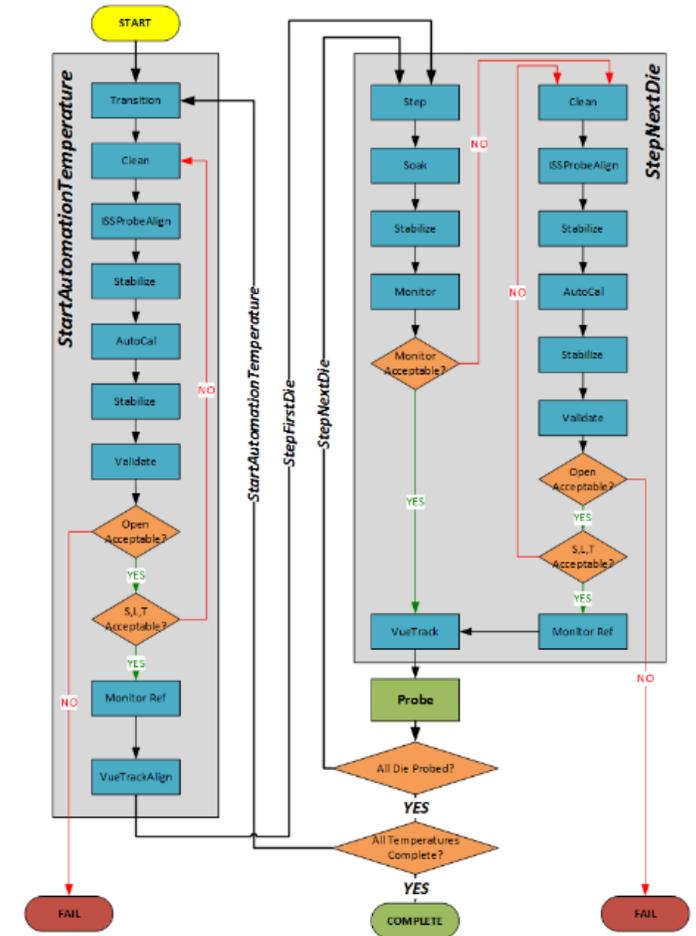
Recording Stopped
Click here to play this recording.

9:41 AM
5/11/2022

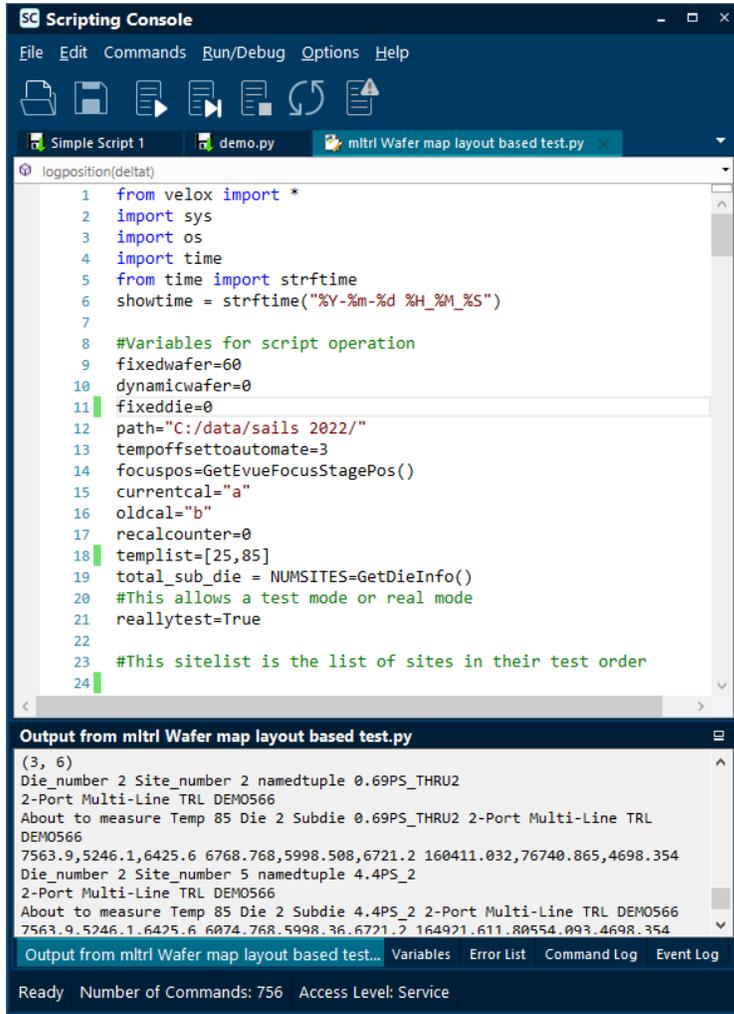
Integrating Automation assistant into test executive

- **StartAutomationTemperature X** does all this...

- Changes temperature and maintains probe to probe, and probe to wafer geometry at Separate
- Die soak at end of transition at align height always maintaining geometry
- Checks using VNA to test for electrical stability
- Moves bias probes out of field of view
- Aligns probes at ISS using defined spacings
- Re-checks stability to ensure probes didn't cool down
- Calibrates system
- Verifies
- Takes monitoring data to check system is stable later on
- Returns probes to wafer Geometry ready for test
- Additional options of this command performs Theta align and sizing
- This command would already be used by Vuetrack customers although typically they typically don't do RF



Measuring Using Autonomous RF Measurement assistant



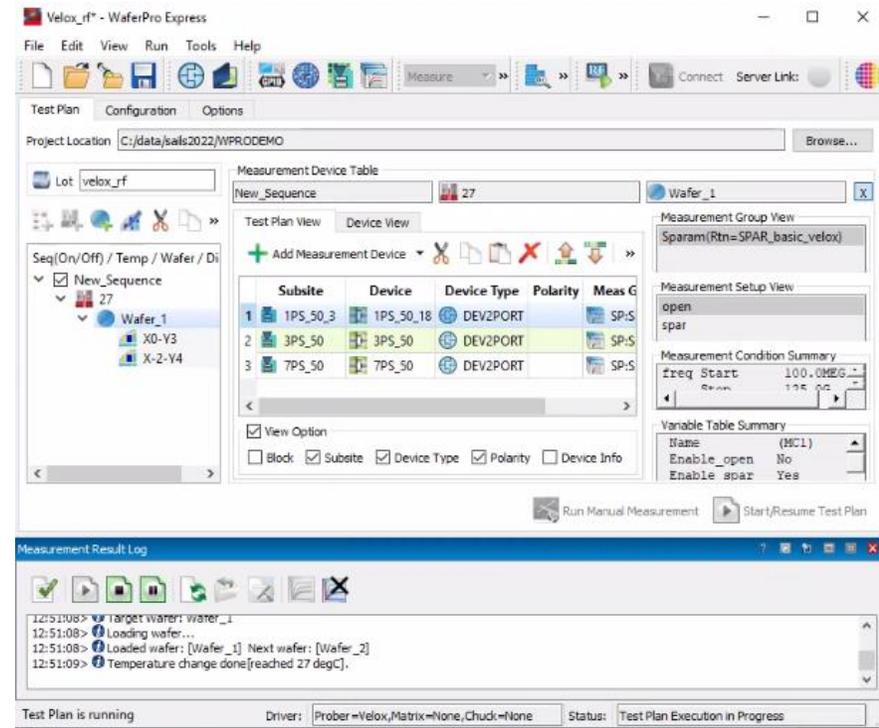
```
logposition(deltat)
1 from velox import *
2 import sys
3 import os
4 import time
5 from time import strftime
6 showtime = strftime("%Y-%m-%d %H_%M_%S")
7
8 #Variables for script operation
9 fixedwafer=60
10 dynamicwafer=0
11 fixeddie=0
12 path="C:/data/sails 2022/"
13 tempoffsettoautomate=3
14 focuspos=GetEvueFocusStagePos()
15 currentcal="a"
16 oldcal="b"
17 recalcounter=0
18 templist=[25,85]
19 total_sub_die = NUMSITES=GetDieInfo()
20 #This allows a test mode or real mode
21 reallytest=True
22
23 #This sitelist is the list of sites in their test order
24
```

Output from mltrl Wafer map layout based test.py

```
(3, 6)
Die_number 2 Site_number 2 namedtuple 0.69PS_THRU2
2-Port Multi-Line TRL DEM0566
About to measure Temp 85 Die 2 Subdie 0.69PS_THRU2 2-Port Multi-Line TRL
DEM0566
7563.9,5246.1,6425.6 6768.768,5998.508,6721.2 160411.032,76740.865,4698.354
Die_number 2 Site_number 5 namedtuple 4.4PS_2
2-Port Multi-Line TRL DEM0566
About to measure Temp 85 Die 2 Subdie 4.4PS_2 2-Port Multi-Line TRL DEM0566
7563.9,5246.1,6425.6 6074.768,5998.36,6721.2 164921.611,80554.093,4698.354
```

Output from mltrl Wafer map layout based test... Variables Error List Command Log Event Log

Ready Number of Commands: 756 Access Level: Service



- Autonomous RF has few additional commands beyond regular prober control
- Demo test was with Python but Keysight Wafer Pro Express is used also as well as ICCAP or any high level language
- Wincal and Velox remote control available using existing libraries via socket connection
- Python or other high level languages using WinCal can act as test exec

Quick video on wafer autonomous temperature run

The screenshot shows a control interface for a wafer autonomous temperature run. The interface is divided into several sections:

- Control Center: Chuck**: Contains icons for Material Handling, XY Joystick, and Z Setup. The Z Setup section shows a vertical scale with a green bar indicating the current position, and a 'Contact' status indicator.
- Position From Home**: Displays the current coordinates for Positioner 1 and Positioner 2. All X, Y, and Z coordinates are 0.0 μm .
- Scripting Console**: Shows a Python script for controlling the wafer map layout based test.py. The script includes comments and code for setting up a test run, including variables for wafer type, path, and site list.
- Output from mltrl Wafer map layout based test.py**: A section for displaying the output of the script execution.

```
4 import time
5 from time import strftime
6 showtime = strftime("%Y-%m-%d %H_%M_%S")
7
8 #Variables for script operation
9 fixedwafer=60
10 dynamicwafer=0
11 fixeddie=0
12 path="C:/data/sails 2022/"
13 tempoffsettoautomate=3
14 focuspos=GetEvueFocusStagePos()
15 currentcal="a"
16 oldcal="b"
17 recalcounter=0
18 templist=[25,85]
19 total_sub_die = NUMSITE$=GetDieInfo()
20 #This allows a test mode or real mode
21 reallytest=True
22
23 #This sitelist is the list of sites in their test order
24
25
26 sitelist=[1,4,8,2,5,9]
27 sitespertemp=3
28
29 #Initiate coms to Wincal
30 sys.path.append('C:\\Program Files (x86)\\Cascade Microtech\\WinCal XE 4.9\\SysBin')
31 clr.AddReference("WinCalRemoting")
32 import CHI.WinCalRemoting as wincal
33 w=wincal.cWinCalClient()
34 stat=w.WinCalOpenServer('localhost',22778)
35
36 #Load default report
37 RESP=w.ViewerLoadReport(path+"DEMO.wrp")
38
```

“VueTrack”™ only implementation

- Potentially every die has cal structures a user might choose to calibrate with but virtual aux site approach is nominally limited to single set of standards
- Reset of the home on the virtual aux chuck is possible and then regular autonomous will work (for instance after a die step to the reference structure)
- There is another way though Use WinCal sequences within the calibration itself which will use the relevant structure on the current die

Subdie Definitions

Add Subdie Using Grid

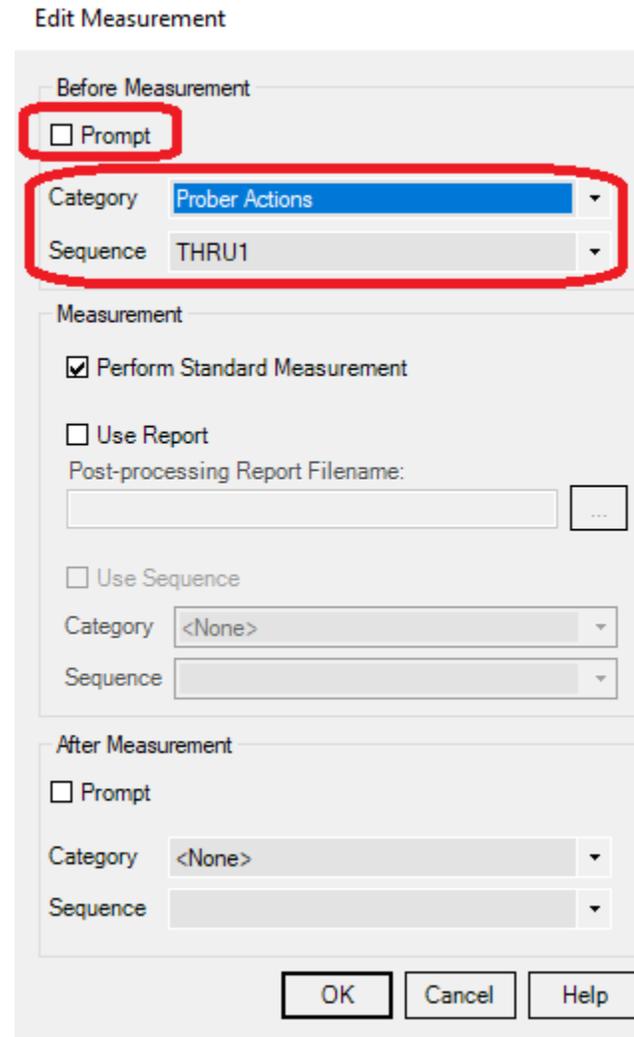
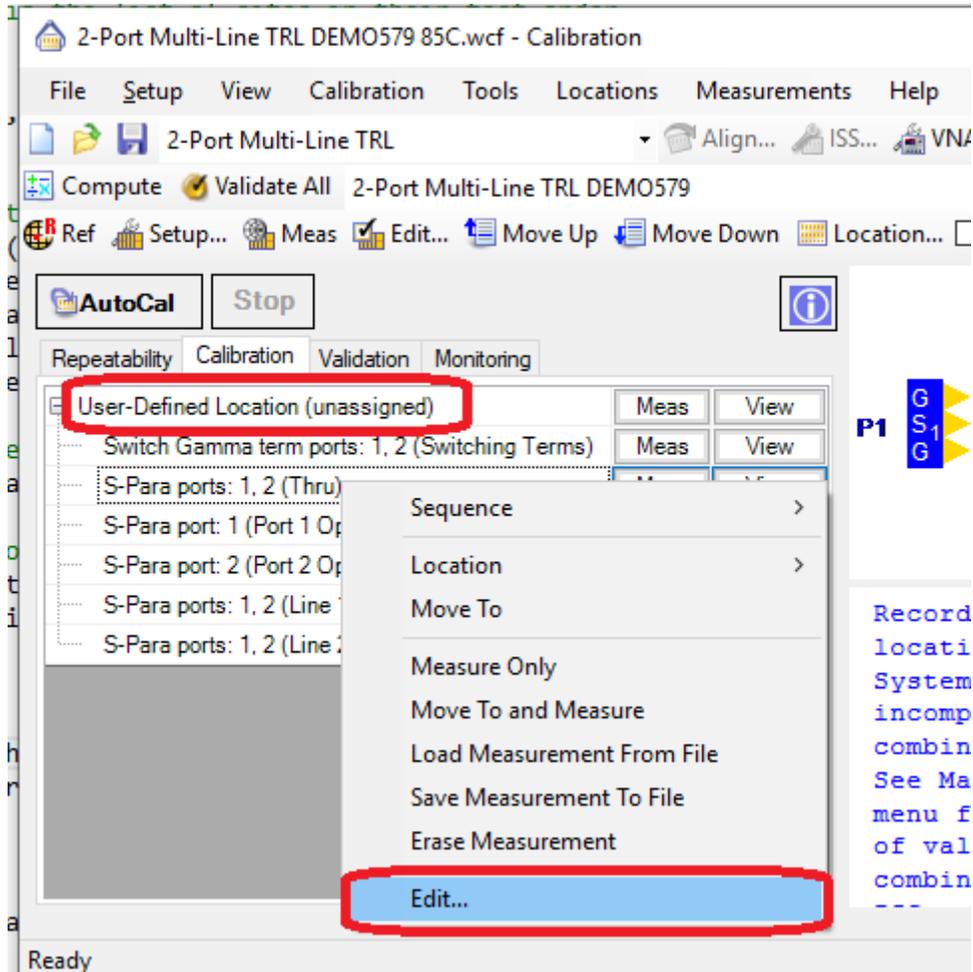
Subdie Definition Table ⓘ

Use Motorized Positioners

Local

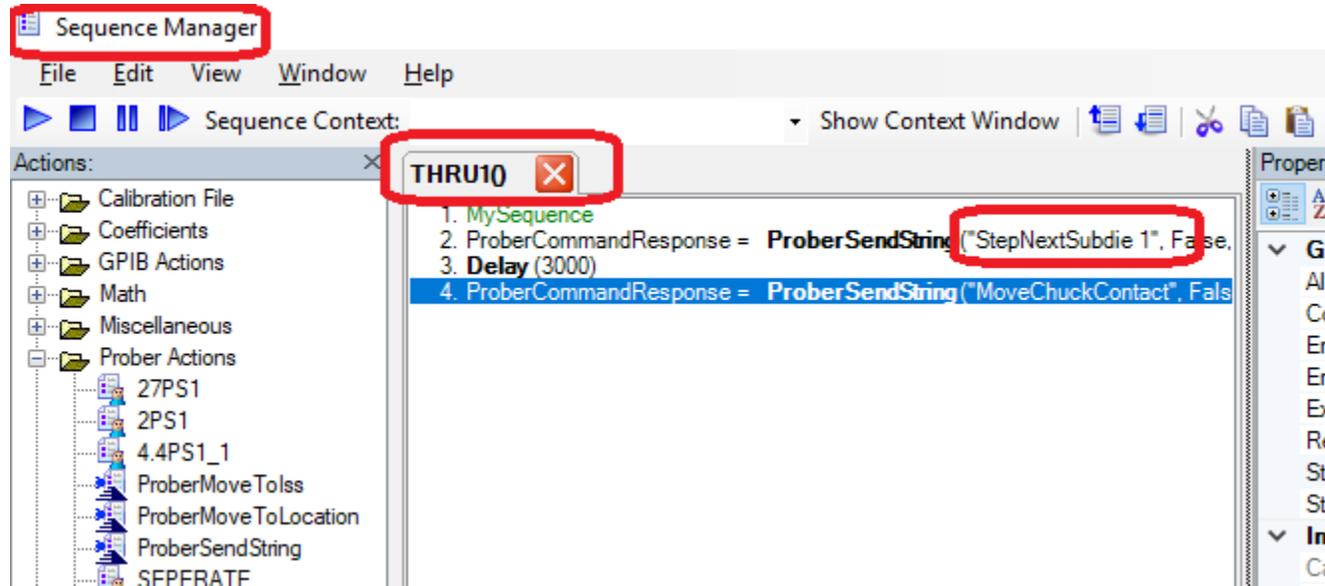
# On	X	Y	Label
0 ✓	0.0	0.0	[Die Origin]
1 ✓	1270.2	0.1	0.69PS_THRU1
2 ✓	2539.3	0.1	0.69PS_THRU2
3 ✓	5074.7	3834.9	2PS_2
4 ✓	696.2	3841.6	4.4PS_1
5 ✓	7048.0	3811.9	4.4PS_2
6 ✓	-2296.1	3807.5	27.6PS_1
7 ✓	-2296.4	5075.0	27.6PS_2
8 ✓	8884.9	5081.6	OFFSET_OPEN1
9 ✓	5076.4	5082.4	OFFSET_OPEN2

"VueTrack"TM only implementation



- Standard has no location associated with it
- Instead the measurement is edited such that a sequence is performed prior to measurement

“VueTrack”™ only implementation



- Sequence has prober command for movement to Subdie 1 (Thru1)
- Subdie tool in Velox automatically handles probe and chuck movement
- This approach DOES NOT automatically test for drift and recalibrate
- It does not dynamically adjust the the probe placement at reference but is recreating the trained geometry. It is essentially a work around but does work pretty well

"VueTrack"™ only measurement run

Control Center: Chuck

Material Handling

XY Joystick

Z Setup

Contact: A: 100.0, S: 250.0, 4729.6, 0.0

Position From Home: X: 0.0 μm, Y: 0.0 μm, Z: 0.0 μm

Spectrum Vision - ON WAFER MLTRL 1*

eVue Camera 10x - 1.7

Updated Automation trained home position

eVue Z: 2064

Wafer Map - C...

Chuck From Home	Positioner 1 From Home	Positioner 2 From Home
X: 0.0 μm	X: 0.0 μm	X: 0.0 μm
Y: 0.0 μm	Y: 0.0 μm	Y: 0.0 μm
Z: 0.0 μm	Z: 0.0 μm	Z: 0.0 μm
T: 0.3125 °		

Y Offset (μm): 14000, 7950.25

Subdie Canvas

THRL

1. MySequ
2. ProberC
3. Delay
4. ProberC

2-Port Multi-Line TRL DEMO575 85C.wcf - Calibration

Repeatability	Calibration	Validation	Monitoring
Switch Gamma term ports: 1, 2 (Switching Terms)	Meas	View	
S-Para ports: 1, 2 (Thru)	Meas	View	
S-Para port: 1 (Port 1 Open)	Meas	View	
S-Para port: 2 (Port 2 Open)	Meas	View	
S-Para ports: 1, 2 (Line 1)	Meas	View	
S-Para ports: 1, 2 (Line 2)	Meas	View	

Record and name a custom location or check if System Setup has an incompatible Probe-ISS/CSR combination by mistake. See Main Window's Tools menu for Viewers of valid probe-ISS/CSR combinations.

Ready Number of Commands: 640 Access Level: Service

Summary

- Autonomous RF works well with MLTRL either off or on wafer
- Off wafer using existing ISS's is easiest but this loses the benefit of the reference plane being at the DUT
- Best on wafer approach uses location manager which is simple to setup but will need re-referencing if there are cal structures on different die required
- Other approaches using sequence tools within WinCalXE are possible